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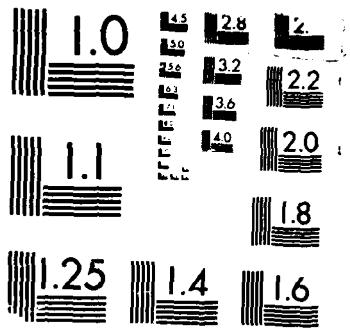

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COMPUTERS IN WEAPONS SYSYEMS:
A LOOK AT THE F-15

MAJOR MICHAEL W. PINTER 88-2135

"insights into tomorrow"

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AUTHOR(S) MAJOR MICHAEL W. PINTER, USAF

FACULTY ADVISOR MAJOR RONALD R. DUFRESNE,
ACSC/3823 STUS

SPONSOR LT COL WILLIAM LAY,
HQ TACTICAL AIR COMMAND/DRFA

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The advance in computer technology has allowed more memory and processing capacity in smaller, more reliable packages. Modern weapons systems are requiring this extra computer memory and processing capacity to succeed on the modern battlefield. This report uses the F-15 aircraft as an example of the computer memory and processing capacity growth in a modern weapons system. The same growth can be expected to continue in the next generation of fighter aircraft. This report also looks at selected F-15 software update management procedures to make recommendations on how to produce more timely, better quality software updates.

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PREFACE

This report reviews the growing importance of computers in modern weapons systems. It also looks at the computer memory and processing capacity growth experienced in the F-15 radar and central computer. Future tactical aircraft weapons systems can be expected to experience similar growth. However, advancing computer technology may allow significant spare memory and processing capacity to be available for incorporation into next generation fighter aircraft. Therefore, proper planning for spare memory and computer processing capacity could significantly reduce or delay costly computer hardware upgrades to these systems. Finally, this report examines current F-15 software update management procedures.

The author would like to express his appreciation to all the F-15 software project managers and engineers at Warner Robins Air Logistics Center, the F-15 System Project Office, Hughes Aircraft Company, and McDonnell Douglas for their efforts in continually producing the quality software updates necessary for providing the F-15 aircraft with superior combat capability.

ABOUT THE AUTHOR

Major Michael W. Pinter graduated from Manhattan College, Bronx, New York on 19 May 1973 with a Bachelor of Engineering Degree in Electrical Engineering. He also obtained a commission in the United States Air Force from the Reserve Officer Training Corps. In November of 1973, he reported to Vance AFB, Oklahoma to attend Undergraduate Pilot Training. He graduated in December 1974 and was assigned to Vance AFB as an Instructor Pilot in the T-38 jet trainer aircraft. During this assignment, Major Pinter received a Masters of Business Administration Degree with honors from the Oklahoma City University. Major Pinter transitioned to the F-15 aircraft and served with the 27th Tactical Fighter Squadron, 1st Tactical Fighter Wing, Langley AFB, Virginia from December 1978 until September 1981. He was then assigned to the 32nd Tactical Fighter Squadron, Camp New Amsterdam, Netherlands from September 1981 until September 1984. During these tours of duty, Major Pinter accumulated over 1,250 flying hours in the F-15 aircraft and served as an F-15 Instructor Pilot and as a Flight Commander. From September 1984 until June 1987, Major Pinter was assigned to Headquarters Tactical Air Command, Air Superiority Division, Directorate of Fighter/Reconnaissance, HQ TAC/DRFA. As a staff officer, Major Pinter was responsible for consolidating the requirements for changes to the F-15 weapons system's software. He also coordinated with Air Force Logistics Command and Air Force Systems Command for the development, testing, and implementation of these changes. Following graduation from the Air Command and Staff College, Major Pinter will be assigned to the 33rd Tactical Fighter Wing, Eglin AFB, Florida where he will once again fly the F-15 aircraft.

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EXECUTIVE SUMMARY

REPORT NUMBER 88-2135

AUTHOR(S) MAJOR MICHAEL W. PINTER, USAF

TITLE COMPUTERS IN WEAPONS SYSTEMS: A LOOK AT THE F-15

I. Purpose: The purpose of this report is to improve planning for weapons systems computer memory and processing capacity growth and the management of weapons systems computer software upgrades.

II. Problem: The importance of computers and effective software management is evident by the numerous regulations, military standards, and directives existing about this subject. Despite this guidance, weapons systems frequently run out of spare memory and processing capacity. Also, software updates are developed, but do not meet operational requirements, and software documentation is often late or inadequate. The author contends that better planning for weapons systems computer memory and processing capacity could reduce the number of computer hardware enhancements required over the life of future weapons systems. Further, weapons systems software update management procedures could be improved to provide more timely, better quality software.

III. Data: The United States is growing more dependent on computers and software updates to help counter the Soviets' conventional numerical superiority. Modern aircraft rely on computers to accomplish all phases of their combat missions. The F-15 is an excellent example of the importance of computers and software updates in modern weapons systems. Over the past fifteen years, the computer memory in the F-15's radar has increased 500 percent and the memory in the central computer has increased 700 percent. During this time, the processing capacity of the radar computer has increased over 2,000 percent. These improvements have been accomplished by numerous computer hardware updates. Unfortunately, the cost of these updates has not allowed their incorporation throughout the F-15 fleet.

Software updates to the F-15's weapons system have provided numerous significant improvements to the aircraft's combat capability. However, some changes to its software have had to be developed several times before becoming operationally effective. For example, the developed Advanced Medium Range Air-to-Air Missile symbology proved to be too cluttered and is being changed as result of operational testing.

Almost every software update to the F-15 has been delayed due to late or inadequate documentation. Warner Robins Air Logistics Center (WR-ALC) has configuration control management responsibility for the F-15 and produces most of the weapons system's software changes. However, current software management regulations do not specify an agency with overall responsibility for software documentation.

IV. Conclusions: The use of computers in modern weapons systems provides a significant increase in combat capability. As systems become more complex and as the threat evolves, more computer memory and processing capacity is required. Future tactical aircraft weapons systems can expect at least the same amount of computer memory and processing capacity growth as experienced in the F-15. Therefore, failure to provide adequate spare memory and processing capacity will necessitate expensive computer hardware upgrades.

User involvement in all phases of the software change development process is essential. Limited operational evaluations of software still in development can prove beneficial in producing better quality software. This procedure can be accomplished by formal agreement between the

developing, supporting, and using organizations. Furthermore, current software regulations do not specify who has overall responsibility for insuring software documentation is produced, reviewed, printed, and distributed in a timely manner. This has resulted in late, and sometimes inadequate, documentation causing delays in software implementation.

V. Recommendations: The Department of Defense and the US Air Force should continue to emphasize the need for spare memory and processing capacity in modern weapons systems. Specifically, growth in memory requirements for future tactical aircraft of up to 500 percent can be expected. This growth should be planned for with spare memory available when the system is fielded or by planned product improvement programs. Growth in processing capacity requirements can also be expected of up to 2,000 percent and should be similarly planned for.

The Department of Defense and the US Air Force should continue to recognize the importance of software updates in improving combat capability. Software change requests should be reviewed for possible operational testing early in the development cycle. Formal procedures for this early operational testing should be developed and incorporated into the appropriate software management procedures.

The F-15 Avionics Operational/Support Configuration Management Procedures should be changed to designate WR-ALC/MMF as the agency responsible for the overall management of software documentation. Documentation milestones should be formally agreed upon by all F-15 software managers during the planning for software development. These milestones should then be reviewed at every technical coordination meeting and design review.

Chapter One

INTRODUCTION

Advances in computer technology have allowed more memory in smaller, lighter, and more reliable packages. Today, virtually every major weapons system produced contains a computer. In current fighter aircraft, computers and software updates have helped sustain and improve operational capability. The importance of computers and software updates in the weapons systems of the United States is growing. However, these weapons systems are continually running out of the spare computer memory and processing capacity. Software updates are developed, tested, and fielded, but do not meet operational requirements. Furthermore, software updates are sometimes delayed due to inadequate or late documentation. This report will look at the F-15 aircraft to discuss these points.

Chapter Two of this paper, will review the growing importance of computers and software updates to counter a numerically superior Soviet threat. Also, the requirement for spare computer memory and processing capacity will be discussed. Proper planning for spare memory and processing capacity can reduce the requirement for costly computer hardware upgrades during the system's life-cycle.

Chapter Three discusses the growth in computer memory and processing capacity in the F-15. This growth has helped to keep the F-15 a state-of-the-art, air-superiority, aircraft. The growth in memory and processing capacity experienced in the F-15 can be used to help determine spare memory and processing capacity requirements in future tactical aircraft.

Chapter Four will review the current F-15 software update management procedures. Specific attention will be placed on software changes that successfully complete development testing, but do not meet operational requirements. Software changes that have been delayed because of lack of documentation will also be discussed.

Chapter Five will present the author's findings, recommendations, and conclusions.

Chapter Two

THE IMPORTANCE OF COMPUTERS IN MODERN WEAPONS SYSTEMS

NATO's military conventional forces are outnumbered by the conventional forces of the Warsaw Pact (1:3-4). This fact puts NATO at a decided disadvantage should a major conflict arise. NATO relies on the superior quality of its conventional weapons systems to counter this imbalance. A primary means of attaining and maintaining superior weapons systems has been by the infusion of computer technology. Edith Martin, a former US Under Secretary for Defense for Research and Advanced Technology, wrote:

> Our potential adversaries, mainly the Soviets, are numerically superior, technologically sophisticated, well equipped, and prepared. We decided to base our defense strategy on superior technology rather than match those adversaries one-for-one in equipment and manpower. ...almost every defense system fielded today contains a computer and has software performing mission-critical functions. The future success of our forces on the battlefield, should conflict arise, will depend on the maturity of our computer technology and its applications (3:9).

The reliance on computer technology in US military aircraft is growing. Pilots are being trained in many aspects of combat by computer simulation. As these simulations become more realistic and cost effective, their use in training pilots for combat has increased. Computers are now aiding pilots in mission planning. The Mission Data Transfer System is becoming operational in F-15 and F-16 aircraft. With this system pilots use a mission planning computer and a data transfer cartridge to initialize some of their aircraft computers. This saves aircraft ground time and fuel since pilots, using this system, no longer manually input numerous navigation coordinates before they taxi. The F-16 flight control system is run by a redundant fly-by-wire system managed by a flight computer. This system optimizes pilot control of the aircraft. The computer even prevents over stressing the aircraft by limiting the amount of "G" forces, or turning capability, depending on aircraft weight,

configuration, and true airspeed. Digital Electronic Engine Control Computers schedule air and fuel flow to modern aircraft jet engines. This improves performance and prevents engine stalls and stagnations as the aircraft aggressively maneuvers throughout an expanded flight envelope. This flight envelope includes low to high speeds from sea level to above 50,000 feet. Today, computers enable one pilot to manage an array of aircraft sensors in a complex combat arena. They provide the necessary steering information for quick arrival within weapon's parameters, and automatic weapon lock-on to the target. Computers even make corrections to the weapon's flight path once it is launched. They also provide warnings of possible hostile enemy fire. All this combined, helps to guarantee successful weapons employment and pilot and aircraft survivability, thus compensating for numerical inferiority.

Computers are ensuring better success both in the air-to-ground and air-to-air mission. The employment of "smart" bombs in Vietnam demonstrated that sophisticated weapons could destroy bridges with fewer sorties than with the use of unguided munitions. Similarly, advances in computers will allow front line fighter aircraft to employ the Advanced Medium Range Air-to-Air Missile (AMRAAM) against several targets at once (4:29). One study prepared for the Air War College summarized the importance of computers in weapons systems as follows:

> ...real leadership in computerized weapon systems could help to maintain this qualitative advantage by means of complex, capable and reliable hardware and software. The potential possibilities of mission-critical computer systems is the only way to regain the technological edge which allowed NATO to believe that quality could substitute for numbers (12:8).

However, one of the major difficulties of modern weapons systems has been the timely infusion and integration of rapidly advancing technology (2:10). Today's fighter aircraft take up to five years to develop. To keep the technological edge, they could require updating before they become operational. In addition, these same aircraft may require several more upgrades to remain effective over their twenty plus years of operational life.

Recognizing the requirement to keep weapons systems updated with the latest technology, the Air Force plans for periodic modifications and additions to these systems (1:8). These modifications are usually cut into existing production lines and then retrofitted back into already produced

systems. However, the integration of new weapons or new sensors, and improvements to complex aircraft sub-systems usually require more aircraft computer memory and processing power. This means, the addition of a new capability often requires improvements to, or replacement of, the aircraft's computers. The added cost of new computers, combined with the extensive time involved in a retrofit program, may prevent older systems from being upgraded. For example, the planned Multi-Staged Improvement Program (MSIP), avionics upgrade to the F-15 aircraft, was incorporated into the last 118 production aircraft. The F-15 MSIP retrofit for the rest of the F-15 fleet will take over 9,000 manhours per aircraft to accomplish. This equates to about four months of depot level maintenance. F-15C/D MSIP retrofit will also cost almost 3 million dollars per aircraft. However, this high cost competes for limited Air Force dollars. As a result, the F-15 MSIP retrofit has already been stretched out and may not be accomplished in older F-15 aircraft (13:--).

The evolution in computer technology is providing weapons systems with the initial qualitative edge. As just mentioned, keeping these systems technologically superior by retrofit has proven to be costly. The cost increases if the improvements require extensive integration and new computer hardware. Improvements requiring only the modification of system software, on the other hand, can be accomplished at less cost and in a more timely manner. Software upgrades can be implemented throughout the fleet at little cost per aircraft, and with practically no system down time. Software upgrades, by themselves, have also provided significant improvements to operational capability and have allowed the flexibility needed to respond to a changing threat.

Software upgrades in the radars, electronic countermeasure systems, and radar warning receivers, of tactical aircraft quickly respond to evolving threats. Improvements to many new weapons and aircraft sub-systems are largely controlled by software. Moreover, pilot interface with the aircraft weapons system is critical to combat effectiveness. This interface is also largely controlled by software.

> ...a computerized weapons system is not basically dedicated to data processing. Its main mission is to monitor, command, and control the working of automated processing, while taking into account the continuous evolution of the external environment by means of numerous sensors (12:12). ...As a matter of fact flying a tactical fighter becomes more and more the ability to control and direct the system through a tailored interface

which is called the operational software (12:16).

Making major improvements to a weapons system can be limited by the available computer spare memory and processing capacity. Increasing memory or processing capacity by upgrading or replacing existing computer hardware adds to modification costs. A weapons system acquisition challenge becomes providing enough excess memory and processing capacity when the system is first produced. Having spare computer memory and processing capacity could limit the number of computer hardware upgrades necessary over the system's life cycle. When enough excess capacity exists, the challenge becomes providing timely, quality software updates.

In summary, the US is depending on technologically superior weapons systems to counter a numerically superior adversary. Advances in electronics and computers are helping to maintain the required superiority. However, infusing new technology, by retrofit, into existing weapons systems has been limited by the high cost of integration and new system hardware. Computer software upgrades, on the other hand, have proven to be a cost effective and timely method of upgrading weapons systems. Significant improvements to system software takes increased computer memory and processing capability. Acquisition of adequate spare computer memory and processing capacity allows the addition of new weapons and capabilities without replacing or enhancing computer hardware. As a result, over the life of the weapons system, the overall number of computer hardware upgrades may be reduced.

The next chapter will look at the computer memory and processing capacity growth experienced in the F-15 weapons system. It will also discuss some of the major increases in combat effectiveness obtained through software updates. The author contends that new tactical aircraft will be more complex than the F-15, and will rely more heavily on computers to perform mission critical functions. These new aircraft will probably require computer memory and processing capacity growth in excess of that experienced in the F-15.

Chapter Three

COMPUTER MEMORY AND PROCESSING CAPACITY GROWTH IN THE F-15

This chapter will review how the computer memory and processing capacity in the F-15 radar and central computer (CC) has grown over the years. How this growth has been used to keep the technological edge in the F-15 weapons system will also be discussed. This growth can then be used as a reference in determining spare computer memory and processing capacity requirements for future aircraft.

The development of the F-15 represents a significant increase in the use of computers to enhance a weapons system. The first operational F-15 was delivered to the Air Force in 1974. This aircraft was equipped with state-of-the-art avionics, integrated with a pilot orientated cockpit. System design allowed the pilot hands-on-stick-and-throttle weapons system control. Advanced cockpit radar and heads-up displays provided quick interpretation of target position and weapon employment options. These improvements justified one pilot (single seat) operation in the demanding air-superiority mission. The Hughes APG-63 pulsed-Doppler radar, with a phased array antenna and 16K radar data processor (RDP), allowed superior target track even through lookdown ground clutter (9:A-II-1). Computer generated digital display of target heading, altitude, and airspeed, coupled with numerous automatic radar modes of operation, made this system superior to its predecessor, the F-4. For example, in the F-4, interpretation of target position and movement on the radar scope vs look angle and own aircraft altitude was required for the weapons system operator to calculate target heading, airspeed, and altitude. This information, along with steering displays for target intercept or weapons employment options, is automatically provided to the F-15 pilot.

The <u>F-15 Avionics Operational/Support Configuration Management Procedures</u> (8:2-3) describes the heart of the F-15 weapons system as the Central Computer (CC). The CC is a general purpose digital computer. It interfaces with twelve avionic subsystems via digital multiplex electrical busses. Although some of the sub-systems perform their own generic computations, the CC performs all mission orientated calculations. The CC then passes this information to and

from the various sub-systems through appropriate analog-to-digital and digital-to-analog converters. The CC takes radar target track information and computes and displays weapons parameters and launch information (9:A-II-1). The CC software, called the operational flight program (OFP), is divided into eight separate modules to allow for flexibility in changing the program. If communication between the radar and the CC should fail then the radar data processor (RDP) can control the system to sustain combat. Because of the dependence of the radar on the CC to calculate and display target information, any major changes to the radar or the CC OFP usually necessitates a change to the other OFP.

While this initial system proved effective, operational testing generated requests for improvements (9:1-5). More radar and CC memory was required to accommodate software changes. In 1978, the 16K RDP was replaced with a 24K solid state computer (15:--). In 1980, the CC memory capacity was doubled to 32K (15:--). Software upgrades to the radar and the CC added several important electronic counter-countermeasures (ECCM) features, numerous display improvements, enhanced radar automatic lock-on modes, better quality radar target tracking, and better radar resolution of several targets flying close together (14:--).

In 1981, the RDP memory for F-15 C/D aircraft was expanded to 96K and a programmable signal processor (PSP) was added to the system. The new PSP was designed to "...perform radar signal processing at high speeds in place of the hardwired processor" (8:5). This increase in processing capacity allowed improved multiple target discrimination (11:94) and the development of the track-while-scan mode of operation. This new radar mode gave the pilot digitally displayed information on several targets at the same time. The addition of the PSP also provided the processing capability for greatly enhanced ECCM.

The development of the Advanced Medium Range Air-to-Air Missile (AMRAAM), the integration with the F-15 weapons system of the new AIM-9M heat seeking missile, and an updated AIM-7M radar missile, necessitated a new 128K CC, and an expanded 348K PSP. These improvements were incorporated into the FY84 F-15 production aircraft buy as part of the F-15 Multi-Staged Improvement Program (MSIP) (13:--).

The growth in the F-15 radar and CC computers shows the importance of computer memory and processing capacity in providing enhanced combat capability. To provide the memory and processing capacity in the F-15, the Air Force developed and incorporated numerous computer hardware upgrades. Unfortunately, some of these improvements have not been

retrofitted throughout the F-15 fleet primarily due to the cost. If initial procurement of, or improvements to, the F-15 had included more spare memory and processing capacity, the Air Force may have been able to forego or delay some computer hardware upgrades.

The F-15 as a weapons system is about 15 years old. Since this system was first produced the growth in the weapons systems computers' memory and processing capacity has been significant. The APG-63 radar RDP core memory grew from 16K to 96K a growth of 500 percent. The CC memory expanded from 16K to 128K, a growth of 700 percent. The radar processing capacity experienced the largest growth. Initially, the 16K RDP performed the radar processing functions. The current F-15 PSP has 348K of processing capacity, an increase of over 2,000 percent. Still, one of the major limitations in the F-15 weapons system is the lack of computer memory. All of the spare memory in the 24K RDP and the 96K RDP has been used (13:--). Additions to the software in these computers will require further computer hardware enhancements.

Future tactical aircraft can expect similar growth as experienced in the F-15. Computer technology is continuing to advance at a fast pace. The development of Very High Speed Integrated Circuits could provide a large increase to computing capacity. Today, extra computer memory can be packaged into smaller, lighter, and more reliable boxes. These advances may allow for significant spare memory and computing capacity to be available when our next generation fighter aircraft are produced. However, cost reduction pressures could cause spare memory and computing capacity to compete against other requirements for incorporation into aircraft design. If the Air Force elects not to provide for significant spare computer memory and processing capacity in initial aircraft, then future costly computer hardware upgrades will probably be required.

Chapter Four

F-15 SOFTWARE UPDATE MANAGEMENT PROCEDURES

The ability to reprogram software significantly aids in keeping weapons systems superior. Software modifications are usually required to add new weapons, sensors, or sub-systems. Software changes can enhance weapons system/pilot interface, thus increasing combat capability quickly and cheaply. In explaining the necessity for software modifications, an Institute For Defense Analysis paper states:

> The single overwhelming commonalty that existed among the systems investigated was the requirement to accommodate change. Refinements to problem solutions and changes to the environment in which the system will be deployed all require modifications to the software (10:77).

For example, newly developed airborne radar deception jamming techniques may be defeated by changing the target data processing in aircraft radars. The ability to quickly implement a software change negates this new threat in minimum time.

Software programs have grown in size and complexity. A Rand Corporation study, <u>Acquisition and Support of Embedded Computer System Software</u>, points out that weapons systems software must operate in real time, interface with many sub-systems, compensate for hardware deficiencies, and have to be reliable during rapidly changing environments (5:17). The difficulties of producing quality weapons systems software has grown with the complexity of the systems (5:69). Air Force procedures on computer software management have evolved to produce better quality software updates and improve software configuration control.

Air Force Regulation 800-14, <u>Lifecycle Management of Computer Resources in Systems</u> describes valid reasons for requesting software changes (6:17). Some of these reasons include: correcting deficiencies, enhancing capabilities, modifying system interfaces, improving the software operating efficiency, improving system reliability, and removing no longer needed capabilities. This regulation also outlines the change process (6:17-19) summarized as follows: The

formal routine software change process starts with a change proposal. This proposal can be generated by any organization that has a role in implementing, using, or supporting the system. An engineering evaluation is performed to ensure a requested software change can be developed. The change is then combined with other approved changes and incorporated into a software development contract or produced organically. Development of the change includes functional design, detail design, coding and checkout, informal testing, formal testing, integration, and flight development test and evaluation (DT&E). During this time the software documentation is produced. The new software is finally released to the user for operational test and evaluation (OT&E) before it is incorporated into the fleet.

These procedures are expanded for the F-15 weapons system in the <u>F-15 Avionics Software Computer Resources Integrated Support Plan</u>, (F-15 CRISP) (7:--), and the <u>F-15 Avionics Operational/Support Configuration Management Procedures</u>, (F-15 O/S CMP) (8:--). By these procedures, F-15 weapons system software change requests are reviewed, prioritized and approved by Headquarters Tactical Air Command, Deputy Chief of Staff Requirements (HQ TAC/DR). These requests are submitted to Air Force Logistics Command (AFLC), and Air Force Systems Command (AFSC) for evaluation, approval, and incorporation into new software development packages. Once the changes are developed and tested, HQ TAC/DR directs its two test centers to perform OT&E before the software is released.

This system has worked well for the F-15. However, as the HQ TAC F-15 weapons system software upgrades project manager from March 1985 to May 1987, the author noted two recurring problems. First, a number of F-15 software changes for each software update were redesigned or modified after successfully completing DT&E. Secondly, several newly developed software packages were delayed in being released because of inadequate or late software documentation.

The first problem is a result of the nature of weapons system software and limitations of DT&E. Weapons system software is highly complex and must perform in a dense electromagnetic environment. Software development is not an exact science. Changes to an OFP could have undesirable side effects to other portions of the program. What appears to be a simple solution may not have the desired effect in the operational environment. Also, pilot/system interface, controlled by software, is critical to mission success. Software provides the pilot with required information and allows him to operate the weapons system while performing numerous simultaneous tasks. These tasks include flying the

aircraft, monitoring wingmen, assessing the rapidly changing tactical situation, and switching radio frequencies. Accurate information must be displayed so the pilot can easily view and understand it at a quick glance. Developmental flight test is not accomplished in such a demanding environment. Developmental flight test is highly structured, usually flown single ship, and limits changes to the external environment so the test pilot and aircraft recorders can closely monitor specific software performance under controlled conditions.

The dynamic nature of the weapons system software combined with the rigid structure of DT&E allow some software changes to perform as specified, but still not meet operational needs. For example, a software change designed to detect radar deception jamming was designed, developed, and implemented. This change had to be redesigned after successful completion of DT&E because in the operational environment target aircraft aggressive maneuvering was being falsely displayed as jamming (14:--).

Another good example is the development of the AMRAAM symbology. This symbology was developed using inputs from F-15 pilots flying a modified simulator (13:--). Unfortunately, the simulator portrays perfect radar performance. As a result, radar target tracks are constant and steady. The AMRAAM symbology was designed and developed based on the this perfect environment. This symbology is now being flown in the F-15 aircraft as part of the AMRAAM OT&E. In the operational environment, radar target tracking is not perfect nor is it constant. Fluctuations in the target tracks in the real world environment makes the AMRAAM symbology jump around on the display. When several targets are present the symbology becomes too cluttered for effective pilot use (13:--).

In both of these examples, the software was redesigned to accommodate the effective system use in the operational environment. However, present software management procedures dictate that software changes complete development testing before operational testing is begun. In most cases, this procedure makes sense. Software engineers go through a methodical process to design, code, checkout, integrate, test, and document each software change. Each change may effect several portions of the overall program. A stabilized software baseline and well defined change requirements are necessary to allow the engineers to complete this involved process in an effective, timely manner. Also the engineers are under obligation, usually by contract, to deliver specified software changes in a given amount of time for a given amount of money. Redefining software change

requirements, once major development work is accomplished, requires the developer to spend extra time and effort on the change. As a result, the contracting agency and the developer are usually unwilling to redesign changes that meet the requirements of the contract even if the changes are not optimized for the operational environment. The using organization is then faced with a decision. Do they withhold implementation of a block of software because some changes do not meet operational requirements; or do they implement the block of changes and wait up to two years for the next software update to fix the undesirable changes? Neither of these options is optimum.

There are several things that can be done to improve this situation. The developers and managers of software changes must be aware of the dynamic operational environment in which pilot/weapons system interface is critical for success. Recognizing this fact, each requested software change should be screened for the possibility of significant impact to the overall pilot/system performance. Once these changes are identified, then special arrangements can be made to have them flown in OT&E early in the DT&E process. These arrangements include making provisions in the software development contract for this procedure, having the developer provide a software test tape as early as possible in the development process for OT&E evaluation, and then using the OT&E evaluation to make recommendations for final adjustments to the change. This procedure, called "Quick Look," has been used successfully in the past on an infrequent and informal basis. To make this procedure effective it needs to be formalized by written agreement between AFSC, AFLC, and HQ TAC. Quick Look procedures should be incorporated into both the F-15 CRISP, and the F-15 OS/CMP.

The second problem involves delayed software releases due to late or inadequate documentation. This problem was highlighted in the F-15A/B radar software release scheduled for 1985. Once this OFP was developed and tested it was discovered that the F-15 technical manuals would not be updated with the software information until after the next scheduled software release. As a result, the 1985 F-15A/B radar software release was cancelled. This problem was again highlighted in the scheduled June 1986 F-15C/D weapons system software release. The operational F-15 community desired this software package in time for the October 1986 William Tell competition. Again, problems with the software documentation delayed the release of this software update until after October 1986.

Warner Robins Air Logistics Center (WR-ALC) is the responsible organization for the F-15 software documentation.

However, the F-15 software management procedures, currently outlined in F-15 OS/CMP, do not specify a particular agency within WR-ALC responsible for the overall management of software documentation (8:13-14). As a result, there is no agency monitoring software documentation progress as the software is being developed. Nor is there any one agency tasked with the responsibility of insuring that the software documentation is reviewed, published or distributed with the software itself. The F-15 OS/CMP states: "WR-ALC/MMF F-15 System Program Management Division, ...has configuration management responsibility for the F-15 field weapon system in general and support for the CCOFP/PSDP/PACS OFP in particular" (8:13). It makes sense to include the overall management responsibility of software documentation with this agency. The F-15 OS/CMP should be updated to include this responsibility for WR-ALC/MMF. This document should also be updated to include procedures for setting milestones for OFP documentation development, review, printing, and distribution. These milestones should be agreed upon by all involved software managers during the planning for the update. Review of these documentation milestones should then take place at every software Design Review and Technical Coordination Meeting.

Chapter Five

FINDINGS, RECOMMENDATIONS, AND CONCLUSIONS

This paper has reviewed the importance of computers in modern weapons systems, shown the computer memory and processing capacity growth in the F-15 aircraft, and discussed two particular F-15 software update management procedures that are not optimized. The findings of this report are described below.

First, the use of computers to provide required technological superiority in modern weapon systems is increasing. Edith Martin sums this idea up as follows:

> Mission-critical computer systems of the future will need very capable, highly complex, and extremely reliable hardware and software. Requirements in each of these areas continue to grow rapidly - almost at an exponential rate (3:9).

Second, software updates can significantly increase the overall combat effectiveness of a weapons system. These updates can be limited by available spare memory and computing capacity.

Third, numerous computer hardware upgrades were necessary to provide the increase in the memory and computing capacity required in the F-15 weapons system.

Fourth, in a span of 15 years, the memory in the F-15 aircraft radar computer grew 500 percent, the central computer memory grew 700 percent, and the radar processing capacity grew over 2,000 percent. This rate of growth can be expected in future tactical aircraft.

Fifth, some software changes require testing in an operational environment before they can be optimized for operational use.

Sixth, late software documentation has delayed the release of several software updates.

Finally, current F-15 software update management regulations do not specify an agency responsible for the overall management of software documentation.

From these findings the author makes the following recommendations. First, at least 500 percent spare memory and 2,000 percent spare computing capacity should be available in the next generation of tactical aircraft. This spare potential should be incorporated when the aircraft is first produced. Failure to provide this room for growth will probably result in future costly computer hardware upgrades.

Secondly, "Quick Look" procedures should be formalized and incorporated into the F-15 software update management procedures. When these procedures are established and their utility verified then they should be incorporated Air Force wide.

Finally, the F-15 OS/CMP should be updated to specify WR-ALC/MMF as the agency with overall responsibility of software documentation. WR-ALC/MMF should be tasked to establish milestones for documentation development, review, printing, and distribution. These milestones should then be briefed and reviewed at each software technical coordination meeting and design review.

In conclusion, this report has shown how the United States and her allies are dependent on technology to counter a numerically superior threat. Virtually every modern weapons system contains computers with mission critical software. Spare memory and processing capacity in modern weapons systems are required for the addition of new weapons and sensors. Furthermore, improvements in software can permit increased combat capability without costly physical modifications to the equipment itself. Proper planning for spare memory and processing capacity in the next generation of tactical aircraft could allow added flexibility in responding to an advancing threat. Software is becoming more critical to system performance in the modern combat arena. The ability to produce timely, quality software updates has become essential to mission success. Software update management procedures must insure this flexibility.

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